Gluon saturation effects on the color singlet J/ψ production in high energy dA and AA collisions

Fabio Dominguez

IPhT Saclay

November 10th, 2011

Motivation

- J/ψ dissociation as signal of QGP formation
- In order to quantify hot matter effects it is necessary to have cold nuclear matter effects under control
- Modified production vs suppression

J/ψ Hadroproduction

- Dominated by gluon fusion
- J/ψ does not have the same quantum number as two gluons
- $g + g \rightarrow J/\psi + g$
- Color singlet model
- Color evaporation model

J/ψ production in pA collisions

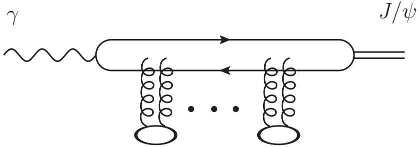
- More gluons are available for production by gluon fusion
- Consider nuclear enhancement where $\alpha_s^2 A^{1/3} \sim 1$
- $g + g + g \to J/\psi$ is dominant
- Without further emissions, the $c\bar{c}$ pair should have the appropriate quantum numbers after scattering

Production accounting for multiple scatterings

- It is necessary to resum multiple scatterings
- After multiple scattering, the $c\bar{c}$ pair must be on a color singlet state
- Projection into J/ψ wave function accounts for selecting the correct parity state

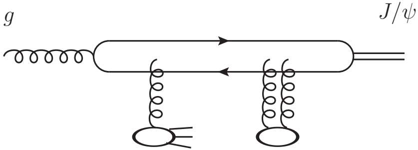
Color structure

Photoproduction



- Starts in a singlet state. No color rotations needed
- Color dipole

Gluon fusion

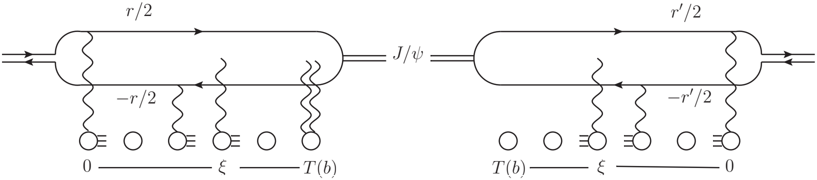


- Starts as an octet. Transition to a singlet state is needed
- Not an usual color dipole (quadrupole)

Resummation of multiple scatterings

- Take large N_c limit
- Before including evolution, use two-gluon approximation (MV model)
- Only one color rotation which can be singled out

Resummation of multiple scatterings



- Before color rotation, the quark and antiquark lines are color disconnected and interactions involving both lines are N_c suppressed
- After color rotation, only elastic scatterings are allowed

Cross section for $p + A \to J/\psi + X$ (before evolution)

- Integrate over position of color rotation
- Include gluon distribution for proton projectile

$$\frac{d\sigma_{pA\to J/\psi X}}{dy d^2b} = x_1 G(x_1, m_c^2) \int_0^1 dz \int \frac{d^2 r}{4\pi} \Phi(\boldsymbol{r}, z) \int_0^1 dz' \int \frac{d^2 r'}{4\pi} \Phi^*(\boldsymbol{r'}, z') \\ \times \frac{4\boldsymbol{r}\cdot\boldsymbol{r'}}{(\boldsymbol{r}+\boldsymbol{r'})^2} \left(e^{-\frac{Q_s^2}{16}(\boldsymbol{r}-\boldsymbol{r'})^2} - e^{-\frac{Q_s^2}{8}(r^2+r'^2)} \right)$$

Rapidity dependence

- Exponentials in previous formula are really dipole amplitudes
- Rapidity evolution of dipole amplitudes is known
- This approach relies on a Gaussian approximation which is not necessarily preserved by the evolution (current studies under way)

From pA to AA

- Use KLN approach
- Same as letting the $c\bar{c}$ pair scatter off both nucleus

$$\frac{d\sigma_{A_1A_2\to J/\psi X}}{dy\, d^2b\, d^2B} = \int_0^1 dz \int \frac{d^2\boldsymbol{r}}{4\pi} \int_0^1 dz' \int \frac{d^2\boldsymbol{r'}}{4\pi}\, \Phi(\boldsymbol{r}, z)\, \Phi^*_{\lambda\lambda'}(\boldsymbol{r'}, z')\, 2T_{A_1A_2\to JX}(\boldsymbol{r}, \boldsymbol{r'})$$

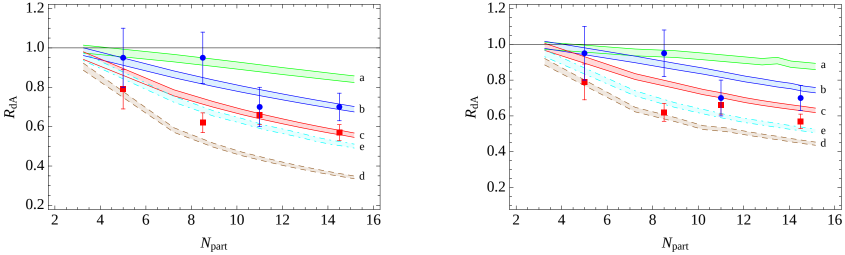
$$T_{A_1A_2\to JX}(\boldsymbol{r}, \boldsymbol{r'}) = \frac{C_F}{2\alpha_s\pi^2} \frac{Q_{s1}^2 Q_{s2}^2}{Q_{s1}^2 + Q_{s2}^2} \frac{4\boldsymbol{r}\cdot\boldsymbol{r'}}{(\boldsymbol{r}+\boldsymbol{r'})^2} \left(e^{-\frac{1}{16}(Q_{s1}^2+Q_{s2}^2)(\boldsymbol{r}-\boldsymbol{r'})^2} - e^{-\frac{1}{8}(Q_{s1}^2+Q_{s2}^2)(r^2+r'^2)}\right)$$

Numerics

- Simplified parametrizations for dipole evolution
    - GBW-type models fitted to DIS data
    - Can be improved by using full BK numerical solution and including proper impact parameter dependence

- pp cross section entering R_{AA} is taken from our formula with $A = 1$ times a normalzation constant

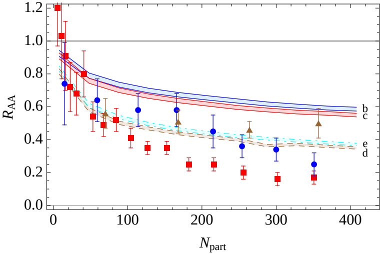
Results for pA

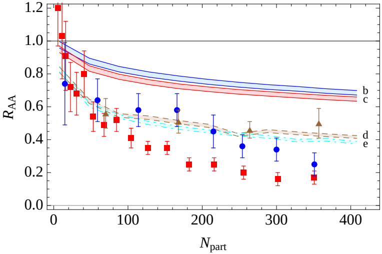


- $y = -1.7,\ \sqrt{s} = 200$ GeV
- $y = 0,\ \sqrt{s} = 200$ GeV
- $y = 1.7,\ \sqrt{s} = 200$ GeV

- $y = 3.25,\ \sqrt{s} = 2.76$ TeV
- $y = 0,\ \sqrt{s} = 5.5$ TeV

Results for *AA*





- $y = 0$, $\sqrt{s} = 200$ GeV
- $y = 1.7$, $\sqrt{s} = 200$ GeV

- $y = 3.25$, $\sqrt{s} = 2.76$ TeV
- $y = 0$, $\sqrt{s} = 5.5$ TeV

Conclusions

- Good as a qualitative estimate
- Accuracy of calculation is not good enough for quantitative comparison with data
- Improvement is possible and new tools are currently under development
- Cold nuclear matter effects do not seem to be enough to account for the total suppression